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## Collective Effects in HEMC10

- Use equations projected on 26.10.
- Compare HEMC at 10 TeV to LHC
- Machine sizes are comparable
- HEMC10 parameters close to official values

•  $\eta \approx 4 \cdot 10^{-5}$

	HEMC10	LHC
Resistive-wall growth rate	2.6/s	6.6/s
Coherent synchrotron tune shift threshold	15 $\mu\Omega$	1.3 $\Omega$
Microwave instability threshold	4 m $\Omega$	6.5 $\Omega$
Transverse mode-coupling threshold	1.9 M $\Omega$ /m	160 M $\Omega$ /m
Chamber material	W	Cu/Fe

- Calculate power deposited within a skin depth of chamber by image current

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## Collective Effects in HEMC100

- Compare HEMC at 100 TeV to vLhc
- Machine sizes comparable
- HEMC100 parameters close to official values
- Non-isochronous HEMC with  $\eta \approx 1.3 \times 10^{-5}$

	HEMC	vLhc
Chamber material	W	Cu/Fe
Resistive-wall growth rate	0.14/s	3/s
Coherent synchrotron tune shift threshold	3 $\mu\Omega$	28 m $\Omega$
Microwave instability threshold	17 m $\Omega$	0.6 $\Omega$
Transverse mode-coupling instability threshold	28 M $\Omega$ /m	420 M $\Omega$ /m

- Most answers so awful that formulae for non-isochronous machines better not be applicable!

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## Isochronous Storage Ring

- No synchrotron oscillations when  $\eta = 0$
- Rigid  $\mu$  positions along bunch, even when  $\mu$  energy changes
- Longitudinal wakefield changes  $\mu$  energy along bunch, expressed by loss factor  $k_{\parallel}$  in  $V/pCb$
- Want accumulated energy changes over  $\mu$  lifetime small compared to RMS energy spread

$$k_{\parallel} \ll \frac{\sigma_e (E/e)}{N_e n_{\text{turn}}} \approx 12 \frac{V}{pCb}$$

- Loss factor  $k_{\parallel}$  includes frequencies up to 0.15 THz

## Isochronous Storage Ring II

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- Transverse wakefield kicks  $\mu$  beam with offsets about equal to RMS beam radius, expressed by transverse loss factor  $k_{\perp}$  in V/pCb m
- Accumulated kicks over  $\mu$  lifetime should be small compared to divergence  $\sigma'$  at IP

$$k_{\perp} \ll \frac{2(E/e)}{N_e n_{\text{turn}} \bar{\beta}} \approx 4 \cdot 10^5 \frac{\text{V}}{\text{pCb m}}$$

- There must be tolerances on  $\eta$ ,  $\eta'$ ,  $\eta''$ , etc. for this theory to apply
- There must be a transition between the  $\eta = 0$  formulae and the  $\eta \neq 0$  formulae with impedances

## More on Collective Effects

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- Another way of looking at these effects is beam breakup BBU
- All phenomena discussed earlier also occur in injectors
- For similar energy and emittances as 4 TeV collider cf. calculations in status report, etc.
- For higher energy and different emittances launch new calculations

## Space Charge in Cooling System

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- According to V. Parkhomchuk a limit on the spatial density of the  $\mu$  bunches arises from a comparison between the longitudinal defocusing due to space charge and the longitudinal focusing by the RF system
- This limit can be transformed into a limit on the density in 6D phase space by taking the  $\beta$ -functions in the transverse direction, and the momentum spread in the longitudinal direction
- All this should be quantified
- We need formulae for cooling rates including space charge

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Numbers from Parkhomchuk

Muon energy 40 MeV

Li lens length 1 cm

RF wavelength 10 cm

RF voltage 1 MeV

Solenoid field 10 T

$\beta_{\perp}$  3 cm

$\beta_{\parallel}$  26 cm

$\epsilon_{\perp}$  0.15 mm

$\epsilon_{\parallel}$  0.23 mm

$\epsilon_{GD}$   $5 \cdot 10^{-12} \text{ m}^3$

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Parkhomchuk's numbers for  $N_\mu$

transverse beam size

$$N_\mu < \left( \frac{\sigma_\perp}{a^*} \right)^2$$

Debye length in Li

$$N_\mu < 4.5 \times 10^{10}$$

Two orders of magnitude short